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SUSTAINABLE TRANSPORT AND THE IMPACT ON THE BUILT ENVIRONMENT: FUTURE TRENDS AND DIRECTIONS.

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Abstract

We love the automobile and the independence that it gives us. We are more mobile than we have ever been before in recorded history. In Australia 80% of journeys are by private motor vehicle. But it is becoming increasingly obvious that this era has a very limited lifespan.

Fuel prices have skyrocketed recently with no end in sight. In spite of massive amounts of road construction, our cities are becoming increasingly congested.

We desperately need to address climate change and the automobile is a major contributor. Carbon trading schemes will put even more upward pressure on fuel prices.

At some point in the near future, most of us will need to reconsider our automobile usage whether we like it or not.

The time to plan for the future is now. But what will happen to our mobility when access to cheap and available petroleum becomes a thing of the past? Will we start driving electric/hydrogen/ethanol vehicles? Or will we flock to public transport? Will our public transport systems cope with a massive increase in demand? Will thousands of people take to alternatives such as bicycles? If so, where do we put them? How do we change our roads to cope? How do we change our buildings to suit? Will we need recharging stations in our car park for example? Some countries are less reliant on the car than others e.g. Holland and Germany. How can the rest of the world learn from them?

This paper discusses many of the likely outcomes of the inevitable shift away from society's reliance on petroleum and examines the expected impact on the built environment. It also looks at ways in which the built environment can be planned to help ease the transition to a fossil free world.

1. Introduction

A little over a hundred years ago the internal combustion engine transformed human civilization. It gave us previously unknown freedom to travel where and when we chose. It allowed symbiotic development of both the car and our cities. In some places the car has displaced all other forms of transport to the point that many parts of our cities are accessible only by the automobile (Black, 2006). "…as long as the car remains the dominant transport mode, sprawl is likely to be the dominant urban form." (Glaeser & Kahn, 2003).

But there is increasing creditable evidence that shows that the automobile cannot continue in its present form. The liquid fossil fuels that power our automobiles are finite and we are reaching the point where our ever-expanding demand for fuel will not be met with increased supply. (Hubbert, 1949) Combined with the imminent danger of climate change, degradation of quality of life through pollution and congestion of our cities it becomes increasingly easy to argue that the business-as-usual approach is no longer appropriate. We can expect that over the next 10 to 20 years the transportation sector will change significantly.

There is a great deal in the literature exploring the current and historical use of transport and its relationship to the built environment. For example: (Sheller & Urry, 2000) (Glaeser & Kahn, 2003). However there is a distinct lack of analysis of the likely future impact that transport will have on the built environment. In fact the overwhelming impression is that of an expectation that cities will continue to sprawl and we will continue to spend vast sums of money on infrastructure to try in vain to keep up with continuously increasing numbers of vehicles on the roads. This unconstrained expansion in itself is clearly unsustainable, however when we also consider issues such as peak oil and limiting greenhouse gas emissions it becomes increasingly difficult to argue that significant changes to what Sheller et al.describe as "automobility" will not occur in the next 20

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years. Once we accept that the future of transport will change significantly in the near future and that our cities, housing social patterns have been defined by the automobile then we can expect that changes to automobility will trigger similar changes to our built environment. Architecture and urban planning involve long time frames and represent massive financial investments. Building a new motorway can take years and we expect it to last for many decades. Public and private buildings also require large financial commitments and so we expect them to last for a long time. By contrast, vehicles can and will change with far greater rapidity. We can see that change is inevitable but we cannot be sure exactly what the future will look like. At best we can only speculate and examine scenarios based on current developments. Speculation is often frowned upon in academic papers. However in this case there is no precedence to examine and so the best we can do is to look to the literature and try to extrapolate various scenarios. This paper examines likely scenarios and the impact of those scenarios. It is important that we do this as the built environment that we plan today will need to suit our needs for a long time to come.

1.1 Definitions

1.1.1 Sustainable Transport.

The word "sustainability" tends to be overused in popular media. It is often used interchangeably with recycling and low energy use. It now seems to apply almost exclusively to "environmental sustainability" however the term should apply to a far broader context. For example, social and economic sustainability need to be considered alongside environmental. For without a stable and sustainable society and economy, environmental sustainability is unlikely to be achieved. "We must also take into consideration the expanding needs of a growing world population, including all its social, economic, ecological, geographical and cultural dimensions." (Nijkamp, 1993)

The Oxford English Dictionary's definition of the word "sustainability" is as follows: from the root "sustain" or "Capable of being maintained at a certain rate or level"

It then follows that in order to ascertain whether a system or thing is sustainable we can submit it to the "Sustainability test" We simply have to ask the question "can this system or thing be maintained into the future indefinitely?" Or, "can we still use this system in 10, 100 or 1000 years from now?" Only if the answer is yes then the system is sustainable. Unfortunately most systems in use today rely on finite resources which will inevitable at some stage become depleted. This means that they cannot be truly sustainable. The use of non-renewable energy sources to power most of our current forms of transport means that they are certainly not sustainable.

1.1.2 Built Environment

Although the term "Built Environment" has arisen from the architecture and construction industry it is now seen to encompass a far wider range of disciplines that vary in scope from regional and urban planning to architecture to Industrial design. It is multi disciplinary and interdisciplinary in character. (Chynoweth, 2006)

Its simplest definition is however its broadest. The built environment can also be seen to encompass all tangible things man-made. Therefore all tangible things either belong to the natural environment or the built environment. This is of course a very broad definition. In this paper I will focus on the areas of architecture and urban planning.

1.2 Defining the problem

1.2.1 History.

Over the last 100 years, the automobile has played an incredibly pivotal role in shaping both our society and our culture. It has given us the freedom to go where we want, when we want. It has allowed our cities to grow by allowing us to live further from our workplaces, further from our schools, further from our shops and further from each other. It has allowed the creation of enormous shopping centres (shopping malls). The corner shop is now on the endangered list. It has allowed the creation of industrial estates and dormitory towns. It has allowed our cities to grow and sprawl to the point that the car is no longer a luxury item but an essential tool for going about our daily business. There have been many studies of how cars and cities co-exist and grow (for example, Sheller & Urry, 2000)

The automobile industry is a major contributor to the economies of many developed nations. For example, "one-tenth of the nongovernmental labor force in the United States is directly dependent upon the production, sales and service of automobiles for its employment." (Huttman, 1973) We are truly addicted to the automobile. But unfortunately automobiles rely on fossil fuels which will not last forever. In fact, it will not last much longer.

1.2.2 Oil resources

The study of peak oil has been well documented in the literature over the last few decades. The following is a brief summary of the topic.

The use of almost any non-renewable resource when plotted against time shows an unmistakable bell curve. At the peak of the bell curve, the supply of the resource no longer meets demand. At this point the use of the resource use will need to be reduced or a different resource used instead. With oil we are approaching that peak. This phenomenon is well observed and was first established nearly 60 years ago. (Hubbert, 1949). The question of when we will reach that peak is an important one. Some very creditable studies show that it has already past us and nearly all believe that the peak will occur before 2013. (Duncan & Youngquist, 1999)

The peak is unlikely to be sharp. It is more likely to be a plateau after which production will continuously and irreversibly decline at around 2% to 3% per year. The world currently consumes roughly 87,000,000 Barrels of crude oil per day or roughly 32,000,000,000 per year. By way of illustration will need to reduce our consumption by around a 1,000,000,000 barrels per year or for every single vehicle in the world (every car, plane, truck, train and motorbike) to stop for 11 days each year.

The predicted economic effects of peak oil vary from apocalyptic to benign. This very much depends on what mitigating actions we take and how far in front of the peak we act. (Robinson, Fleay, & Mayo, 2005). We have the choice of waiting until we can clearly see that we are past the peak or we can choose to act now to mitigate the effects.

1.2.3 The sustainable options

There are several options for sustainable transport and most probably several will at least initially be in use over the next 20 years. As was the case in the early days of the automobile when electric cars and steam powered cars shared the road with petrol powered cars. The types of vehicle can be categorized by their energy source.

2 Direct conversion of existing fleet to bio-fuels such as ethanol and bio-diesel.

These are fuels created from plant matter and used as a direct substitution or as a blend with fossil fuels. Initially the use of biofuel would seem to be an ideal situation for several reasons.

- They can reuse much of the delivery and distribution infrastructure that currently exists for fossil fuels.
- Vehicles need little if any modifications to run on bio fuels.
- Greenhouse gas emissions are theoretically neutralised as the carbon released during the burning of the fuel should be balanced by carbon dioxide fixed in the plant during growth. Therefore no net release of carbon into the atmosphere.

Unfortunately this is not the entire story.

- Maintaining the existing vehicle fleet whilst economically attractive does nothing to address existing congestion and pollution (both atmospheric and noise) problems.
- The production of feedstock to produce bio-fuel requires a large amount of energy for harvest, fertilizing transportation and processing. It has been shown that in the case of corn (the major crop to produce ethanol in the US) the energy used to produce ethanol is equivalent to the energy available for use as a fuel. (ANTI, et al., 2005) Therefore there is little if any net energy gain.
- The major problem with biofuels is that currently it requires large areas of arable land to produce this fuel. This land is typically either;
  - land formerly used for food production.
    - This results in increased food prices and food shortages. (Runge & Senauer, 2007)
  - or land cleared for additional crop planting.
    - From a carbons emissions point of view it has been shown that replanting forests is a better option for carbon mitigation that substituting fossil fuels for bio-fuels. (Righelato & Spracklen, 2007) So we will actually add to carbon emissions by

However:

- Recent developments using algae as a feedstock for the production of biofuel looks very promising. (Hossain, Salleh, Boyce, chowdhury, & Naqiuddin, 2008) Certainly there are benefits using a marine-based organic crop however producing commercial quantities may be difficult without causing damage to fragile marine environments. At this stage the technology will not support commercial production

To use this form of energy as a replacement is at the moment not sustainable. At best it could be seen as an interim measure to minimize the effects of peak oil.

2.1.1 Impact on the built environment.

Because it allows the continued use of the current vehicle fleet it will have little if any impact on the built environment other than a continued demand to built more roads.

2.2 Hybrid electric vehicles

These vehicles use a combination of electric motor and internal combustion engine to drive the vehicle. An example of this type of vehicle is the Toyota Prius.

They rely on the continued use of fossil fuels and although they are more efficient than conventional cars and can play a valuable interim role in reducing our demand for fossil fuels they still do not pass the sustainability test.

Again they have a very minimal impact on the built environment because they are currently intended to be a direct substitute for the conventional car.

2.3 Plug-in Electric Vehicles

These vehicles range from conventional cars with an electric motor replacing the internal combustion engine and a set of batteries replacing the fuel tank. The batteries are recharged by plugging the car directly to a power outlet.

Determining whether this type of vehicle passes the sustainability test is difficult to establish. It depends entirely on what is used to generate the electricity required to charge the batteries. If a renewable source is used such as wind farms, geothermal, or photovoltaic then it is certainly a sustainable solution.

Electric vehicles have been around since the first automobile. In fact at the turn of the century there were more electric vehicles on the road than petrol powered. (Black, 2006)

The biggest drawback historically has been the weight of batteries required to give the vehicle suitable range. Also battery recharging is a lengthy process compared to filling a tank with petrol. Recent developments in battery technology demonstrate that these limitations are no longer a technical limitation although the cost of this emerging technology is still relatively high. Economies of scale associated with large scale production should change this.

Current production electric vehicles such as the Tesla Roadster are designed to be an electric substitution of a conventional car with perhaps some performance improvements. As an interim measure this is understandable but is some ways limits the true benefits of the electric vehicle. The format of a conventional vehicle is dictated by its engine, gearbox and drive-train. Most of the structural strength of the vehicle is required to support the weight of these components. By comparison the motor of an electric car is far smaller and a fraction the weight of an equivalent petrol powered engine. Due to the flat torque characteristics it does not require a gearbox. Also electric motors can be made small enough to be placed inside the wheels of the car. The batteries are the heavy component in an electric car however it is relatively easy to distribute the batteries around the vehicle. This allows design flexibility that was impossible with an internal combustion engine. For example it is now entirely feasible to have all wheels turn through 90 degrees allowing the car to effectively drive sideways. This allows the vehicle to be parked in spaces only slightly longer than the vehicle itself. In addition, the external size of the car can be reduced significantly as the volume required is now only slightly larger than the passenger volume. The obvious concern with a reduced volume around the passenger cell is that of safety. Safety can be improved greatly by the use of advanced composite materials (Lovins, 1995) as well as airbag technology. Other advancements in active safety devices such as ”anti-lock braking systems”, “anticipatory protection systems” and “automatic partial braking” all allow for smaller, safer vehicles. Vehicles such as the “Smart” give an indication of future directions in vehicle design. For these reasons we can expect a significant reduction in size of vehicles if a large part of the fleet changes to electric.

Lovins (1995) argues that the future of the car is what he calls the “hypercar” This is an ultra lightweight electric hybrid vehicle made from advanced composite materials and extremely low drag coefficients. He argues that although the hypercar will have a petrol-electric hybrid motor it will be “cleaner” than the electric only version. He makes the assumption that the electricity will be produced in a non-renewable way. This is not necessarily the case. But his rationale for efficiency through weight reduction is sound whether it is an electric-fossil fuel hybrid or an electric only vehicle. In a conventional car “less than 1 percent of the fuel energy actually ends up hauling the driver.” (Lovins, 1995) The rest is either lost in inefficiencies or is required to propel the vehicle. Reducing the mass of the vehicle reduces the energy required to propel it, regardless of where the energy comes from. Another factor not commonly considered is that of speed. The amount of energy required to push a vehicle through the air rises exponentially with speed. That is to double the speed we require four times the energy. Given that the average commuting speed in many of our cities is less than 20km/h (Dept of Planning ang Community Development, 2006) it does not make sense that we typically drive vehicles designed to carry 5 adults at speeds in excess of 120km/h for the occasional time we require a vehicle like this. We tend to purchase vehicles based on what they are potentially able to do rather than what we really require them to do. A great example of this is the current popularity of the large four wheel drive vehicles that rarely, if ever are driven off road. Or sports cars capable of being driven at speeds of 300km/h that end up being driven to work at an average speed of 19km/h.

What is required is a change in the way in which we view our road systems. We need to start planning segregated roadways and transportation systems that suit our requirements and the requirements of the environment.

2.3.1 Impact on the built environment.

We can expect that the electric vehicle should rapidly evolve to lightweight, externally small (not necessarily internally small) vehicles with far greater maneuverability than conventional cars.

One immediate impact on the built environment is that of car park design. It will be quite feasible to be able to park up to four times the number of vehicles in the same space.

This will allow for far more vehicles

2.4 Lightweight Electric Vehicles (LEV) – hybrid

The next stage in the development is the lightweight hybrid vehicle.

These vehicles are similar to the hybrid vehicles in the way they work however using lightweight techniques allows for efficiency levels 4 to 6 times those of current production cars. (Lovins, 1995)

Although still using fossil fuels, LEV hybrids have the potential to deliver efficiency levels to the point where they could be considered "virtually sustainable".

Lightweight Electric Vehicles (LEV) - plugin

2.5 Hydrogen vehicles

Hydrogen is essentially an energy storage medium rather than an energy source in its own right. In this respect it is similar to a battery. Hydrogen as a fuel is difficult to classify as sustainable or not. As with electric it entirely depends on the original energy source required to produce the hydrogen. There are two options for hydrogen powered vehicles.

The first is the hydrogen internal combustion vehicle. This is essentially a conventional car modified to run on hydrogen. It uses a tank with compressed hydrogen instead of a liquid-fuel tank. An example of this is the BMW Hydrogen 7 which runs on both petrol and hydrogen. The major limitation at the moment is the very low temperature at which hydrogen needs to be stored. The biggest advantage is that conventional vehicles can be used with minor modifications.

The second option is the hydrogen-electric vehicle. This uses a hydrogen fuel cell to create electricity to drive an electric motor. It has all of the design-flexibility options that the electric vehicle has but with a little more complexity with the hydrogen fuel cell. The greatest benefit is the potential weight saving compared to an equivalent battery powered vehicle and is still significantly less complex than an internal combustion vehicle.

All hydrogen vehicles have two drawbacks at the moment.

- Lack of existing infrastructure for hydrogen refuelling – although current fossil fuel distribution and delivery could be modified
- Hydrogen storage requires very low temperatures.

2.6 Public transport

Public transport can be broken into two types. On road and track based. Firstly, road based public transport such as buses and trams are generally considered to be more sustainable than cars due to the increased efficiency. But to be truly sustainable the energy needs to be sourced from a renewable source. For example, an electric tram where the electricity is generated by a hydro electric generator.

2.7 Cycling

The bicycle is the most efficient form of transport. Up to 99% of expended energy is used for forward motion. Compared to the average car at around 20% The energy required comes purely from food. Cycling creates virtually no greenhouse gas emissions. It also has the distinct benefit of being extremely good form of exercise. It is an ideal form of transport for distances up to 10 km. For many inner city distances of around 5km it is also the fastest form of transport.

The major negative is that although it is an ideal form of personal transport, it is not particularly suited to transportation of heavy loads. It also requires a level of exertion that some people find excessive. There are also some people who are physically unable to ride a bicycle. It is ideal for long distance transport due to the low speeds.

Many people already own bicycles. For example 50% of households in Australia have at least one functioning bicycle.

The main reason cited for why people don't cycle more often is because the distances travelled are perceived as too great. (Williams, 2008)

Another reason stated is the weather, although if this really was more than just a perceived problem, one would find that cycling participation was greatest in areas with the most conducive weather. This is not the case.

It is an ideal component in mixed-mode transport. For example it can be used to extend the catchment area of a train station.

It probably the only totally sustainable, readily applicable form of transport.

2.8 Walking

Walking is an ideal means of transport for short distances particularly in crowded CBDs. It is t

I have chosen to use the scenarios set up by Hirsh. By extrapolating the impacts of these scenarios, we can see a picture of some of the likely outcomes. However before that is possible it is useful to analyse the

3 Scenarios

To speculate on what the future impact may be it is useful to look at more than one scenario. Because there is still a great deal of debate about when and how sharp the irreversible decline of oil will be it is very difficult to predict the severity. It is also difficult to predict because there is no historical precedent from which to draw a parallel. According to Hirsch & Wendling (2005) the outcomes depend very much on what mitigation action area taken and how far before the peak they are initiated.

The Hirsch report looked at the following 3 scenarios and compared the impacts of each:

- Scenario 1 assumed that action is not initiated until peaking occurs.
- Scenario 2 assumed that action is initiated 10 years before peaking.
- Scenario 3 assumed that action is initiated 20 years before peaking.

The Hirsch report argues that “Mitigation will require a minimum of a decade of intense, expensive effort, because the scale of liquid fuels mitigation is extremely large.” and “…failure to initiate timely mitigation could be extremely damaging.

Hirsch argues that “the key to mitigation of world oil production peaking will be the construction of a large number of substitute fuel production facilities…” But what are the possible substitutes?

- Hydrogen is not yet ready for large scale production.
- Bio-fuels seem to present more problems than they solve

I would argue that an alternative lies with the electric vehicle. They are probably the most likely alternative transport solution but this is only truly sustainable if the energy to create the electricity is from a renewable source. At the moment most electricity is generated by burning coal, however there are viable, sustainable alternatives such as geothermal, hydro, solar wind etc.

3.1 Speculation

In order to gain an insight into the possible future trends I have looked at the three scenarios set out by Hirsh and attempted to extrapolate them into possible outcomes. I should note that even though it is a projection based on a framework of current technical achievements, the following is my speculation only. The object of which is to provoke discussion on the topic.

3.2 Scenario 1: No action taken before oil resources peak.

This scenario assumes that we do little preparation for the effects of peak oil and it has a devastating effect on our economy. Fuel prices rise dramatically as supply diminishes. Massive inflation occurs due to the cost of everything that involves oil rising. Governments step in and institute fuel rationing and restrict fuel use for essential goods delivery, public transport and the military. The world slips into an economic depression and the major automotive manufacturers disappear. Smaller car manufacturers survive and start making electric vehicles. These are relatively expensive and due to the worldwide recession, take-up is slow. Hypercars are too expensive for anyone other than the rich. Demand for public transport rises much faster than authorities are able to provide it. Some small scale bio-fuel plants spring up but are inefficient and few can afford to buy it. Distribution is sporadic. Cheap, lightweight electric vehicles become popular; especially electric bicycles. Cycling becomes a common form of transport. Hydrogen powered cars are not an option as the costs to implement the infrastructure cannot be met. Electric vehicles are sought after but batteries and other components are hard to source.

Although this sounds entirely negative there are some positives.

- Greenhouse gas emission is greatly reduced.
- Sedentary lifestyle diseases are greatly reduced
- The corner shop becomes common again
- Disenfranchised urban areas gain a sense of identity – especially the outerlying suburbs
- The pace of modern life slows
- Working from home (telecommuting) becomes a common work mode
- Community gardens re-appear
- Houses with garages now gain an extra room

If this scenario happens then there will be little impact on the built environment other than painting extra lanes on the freeways. Job losses and telecommuting will mean much of the CBD office space becomes vacant or is converted to residential. Car parks will become massive bike parks with huge demand for end-of-ride facilities. The reason why there will be so little impact at least in the short term is due to the lack of capital to build with.

3.3 Scenario 2: Action initiated 10 years before peak oil.

In this scenario we are able to convert a reasonable percentage of our vehicle fleet to a renewable energy source. The world still enters a protracted recession triggered by inflationary pressures due to a rapid obsolescence of the remaining internal combustion vehicles. Those vehicle manufacturers that have managed to establish a new market in “green” vehicles survive whilst others disappear. Economic pressures prevent a boom in sustainable vehicles but steady growth continues. Many people seek other forms of personal transport such as cycling, electric bikes and there is a large growth in sustainable public transport. For example we see the return of trams to our cities as well as the return of the corner store. Hydrogen powered vehicles will struggle to gain a foothold due to incomplete refuelling infrastructure and insufficient funds to expand it. Electric vehicles become popular, especially the lightweight versions. Hypercars numbers increase but remain expensive.

The inner city areas of large cities remain vibrant with more pressure for higher density living as people want to move closer to the centre. With less cars on the roads, there is a massive increase in cyclists.

Roads become segregated. Separate roads, not just lanes will suit bicycles and electric bikes with other parts of the roadway for lightweight electric vehicles. Heavy vehicles will be restricted to existing roadways.

Outer suburbs will become less popular and struggle initially. Public transport will play an increasingly important part in travel in these areas. Hubs will form within regional centres and facilities will become decentralised.

3.4 Scenario 3: Action initiated 20 years before peak oil.

How long do we need to smooth the transition from fossil fuels to sustainable transport and prevent economic collapse? “The inescapable conclusion is that in the most optimistic case, more than a decade will be required.” (Hirsch & Wendling, 2005)

So in this scenario I estimate that 20 years will be sufficient to allow a smooth transition to a sustainable economy based on sustainable transport. Cars will be smaller and more efficient with the hypercar or the bicycle being the preferred form of transport. Cars will probably be electric recharged by renewable energy. Alternatively we will have the time to develop the “hydrogen economy” where hydrogen is generated by renewable energy. Public transport will be powered by renewable energy and become as fast and efficient for most journeys as the car. Buses will be smaller and more frequent running more routes. It will again become a viable alternative to the car. The bicycle will be seen as a viable form of transport and in many instances will be seen as the transport mode of choice.

Cyclists will be encouraged with a network of purpose built cycle-freeways. Roads will become segregated so that buses have separate roads or guideways similar to the “OBahn” concept in Adelaide. There will be a range of car classes with zones restricted to Lightweight Electric Vehicles (LEVs) and hypercars.

With an increase in the use of lightweight vehicles and bicycles a different philosophy can be applied to road construction. The concept of the cycle-freeway and the LEV freeway is for an elevated roadway built as flat and as straight as possible. Elevated roadways built to carry heavy vehicles are major construction projects costing vast sums of money. The lightweight nature of elevated cycle/LEV freeways allows them to be built at a fraction of the cost.

Office buildings are constructed with the cyclist in mind. Sufficient end-of-ride facilities are mandated for all new buildings as are cycle parks. Car parks now fit four times as many vehicles.

4 Summary

It is hard to predict exactly what the future will hold for the transportation sector. The only thing we can be reasonably certain of is that we will see some rapid changes over the next 20 years. The business as usual approach will force us to accept the changes as they happen. Whereas we have the opportunity to shape the future the way we want it to be. We have the choice to be either reactive or proactive. The reactive scenario will be far worse than the proactive one.

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